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Stellar Velocity Profiles and Line-Strengths out to Four Effective Radii in the Early-Type Galaxy NGC 3379

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Abstract. We describe a new technique to measure stellar kinematics and line-strengths at large radii in nearby galaxies. Using the integral-field spectrograph SAURON as a 'photon-collector', we obtain spectra out to four effective radii (R_e) in the early-type galaxy NGC 3379. By fitting orbit-based models to the extracted stellar velocity profile, we find that $\sim 40\%$ of the total mass within $5 R_e$ is dark. The measured absorption line-strengths reveal a radial gradient with constant slope out to $4 R_e$.

1. Introduction

Although the presence of dark matter dominated haloes around spiral galaxies is well established (see e.g. van Albada et al. 1985), little is known about the dark haloes around early-type galaxies. Large regular H I discs or rings, whose kinematics are often used to constrain the properties of dark haloes, are rare in these systems (though see Franx, van Gorkom, & de Zeeuw 1994; Weijmans et al. 2008), so that we are forced to use other tracers of the gravitational potential.

Here we use stellar kinematics obtained with the integral-field spectrograph SAURON (Bacon et al. 2001) at large radii in the elliptical (E1) galaxy NGC 3379 to model its dark halo. This galaxy is of intermediate luminosity ($M_B = -20.57$) and has a half-light or effective radius R_e of 42 arcsec, which corresponds to 2.1 kpc at its distance of 10.3 Mpc.

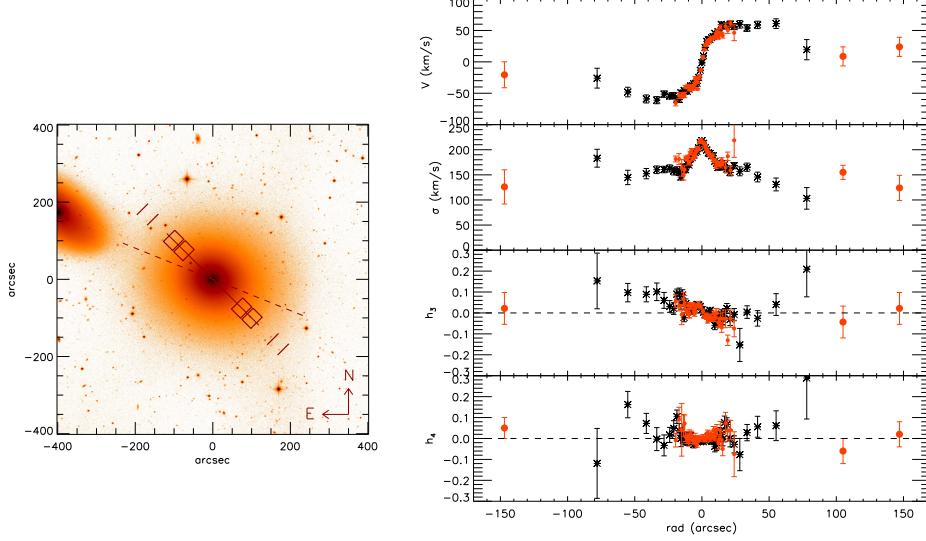


Figure 1. Left: Positions of our observed fields in NGC 3379. The red boxes denote each SAURON field-of-view. The skylenslets (red short thick lines) are aligned with the long side of the SAURON field, at a distance of two arcminutes. The dashed line denotes the major axis of NGC 3379. The underlying V-band image was obtained with the 1.3-m McGraw-Hill Telescope at MDM Observatory. Right: LOSVD of NGC 3379 out to $4 R_e$. The black stars are long-slit data from Statler & Smecker-Hane (1999) and the central red dots are SAURON observations obtained in the original survey (Emsellem et al. 2004). The red dots at large radii are our new observations, and double the spatial extent of the data.

2. Method

We centred SAURON at 2.6 and $3.5 R_e$ on both sides of the nucleus of NGC 3379, close to its major axis (see Fig. 1, left panel). A single spectrum of one lenslet is dominated by noise at these large radii, but adding all spectra of all lenslets together we obtained in three out of our four fields sufficient signal-to-noise to measure the stellar absorption line-strengths and the line-of-sight velocity distribution (LOSVD) up to the fourth Gauss-Hermite moment h_4 . This last parameter is necessary to break the well-known mass-anisotropy degeneracy when modeling the dark halo (e.g. Gerhard 1993).

3. Results

We measured the LOSVD using the penalized pixel fitting method (pPXF) by Cappellari & Emsellem (2004). The resulting LOSVD (Fig. 1, right panel) shows a smooth continuation of existing stellar kinematic measurements (Statler & Smecker-Hane 1999).

We use a Schwarzschild model (van den Bosch et al. 2008; van de Ven, de Zeeuw, & van den Bosch 2008) to fit our measurements, including the central SAURON field of the original survey (Emsellem et al. 2004) and the long-slit data of Statler & Smecker-Hane

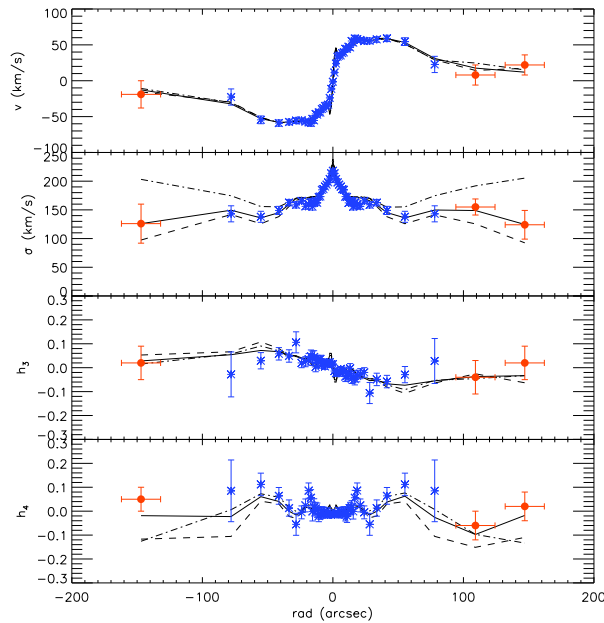


Figure 2. Best-fit model (solid line) overplotted on datapoints. The blue stars are (symmetrized) long-slit data from Statler & Smecker-Hane (1999) and the red dots are our datapoints (horizontal error bars indicate the width of the SAURON field-of-view). Also shown are a model without a dark halo (dashed line) and a model with a ten times too massive halo (dot-dashed line). These models do not fit the observed dispersion and h_4 profiles.

(1999). The black hole mass and the (nearly axisymmetric) shape of the stellar distribution of NGC 3379 are taken from van den Bosch (2008). We model the spherical dark halo with an NFW profile (Navarro, Frenk, & White 1996) with a concentration $c = 10$ (Bullock et al. 2001). Our best-fit model is shown in Fig. 2, and has a total halo mass M_{200} of $1.0 \times 10^{12} M_{\odot}$, which corresponds to 10 times the total stellar mass of NGC 3379.

We obtained line-strength measurements following the procedures outlined in Kuntschner et al. (2006). We find that the slope of the line-strength gradients remains constant out to at least $4 R_e$, although our values of Fe5015 are not consistent with this trend (Fig. 3). Plotting our measurements on the stellar population models of Thomas, Maraston, & Bender (2003), we find that the stellar halo population is old (~ 12 Gyr) and metal-poor (below 20% solar).

4. Conclusion

We showed that by using SAURON as a ‘photon collector’, we can measure both the stellar velocity profile and absorption line-strengths out to large radii in early-type galaxies. We presented our measurements of NGC 3379 and modeled its dark halo. In our best-fit model, 41% of the total mass within $5 R_e$ is dark. We will present more elaborate modeling of the dark halo of NGC 3379 and comparisons with literature values in a forthcoming paper (Weijmans et al.

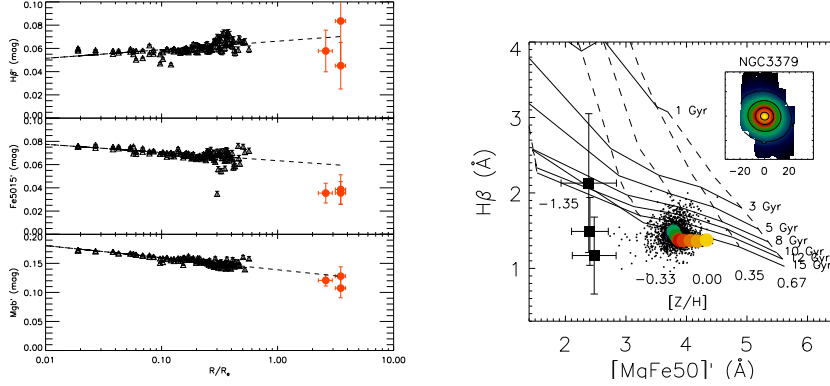


Figure 3. Left: Line-strength gradients (from top to bottom: $H\beta$, Fe5015 and $Mg\,b$, in magnitudes) out to $4\,R_e$ in NGC 3379. Black triangles denote SAURON data from the original survey (Kuntschner et al. 2006), and red dots are our new measurements. Right: $H\beta$ index against $[MgFe50]'$, overplotted on the stellar population models of Thomas et al. (2003). Black dots show measurements from the SAURON survey, while the coloured dots are averaged along isophotes (see inset for colour coding). The black filled squares are our measurements at large radii.

in preparation), as well as a comparable dataset and analysis for the elliptical galaxy NGC 821.

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